Hydropower Development Policy 1992 (Modified) 2001

- After 1990,
- Concept of power system restructuring (establishing competition in the electricity industry) evolved due to open market and liberalization policy adopted by the country.
- Issues of monopoly, transparency, cost and quality of electricity etc. were raised.
- As a result, government invited private sector to participate in the power sector development through promulgation of hydropower development policy, 1992 and the electricity act, 1992.

Hydropower Development Policy 1992 (Modified) 2001

- Electricity act was developed in 1992 for management and development of electricity.

- It incorporates license application, its issuing measures, obligations, License fees, Royalty, Taxes and energy tariffs etc.

Hydropower Development Policy 1992 (Modified) 2001

- It basically incorporates:

1. Implementation of Build, Operate, Own and Transfer Concept.
2. Attracting national and international investment.
3. Effort to implement large storage type and multipurpose projects.
4. Public private partnership policy.
5. Emphasis on hydropower as an alternative of biomass and thermal plants.

Hydropower Development Policy 1992 (Modified) 2001

6. Implement appropriate social and environmental measures.

IEE

EIA

7. Provide reliable and qualitative service to consumers.

8. Royalty to affected municipality, Rural-municipality.

9. Assume local benefit from the projects (Rural electrification, employment etc.)

10. Implementation of training programs to produce skilled manpower.

Hydropower Development Policy 1992 (Modified) 2001

- **The provision of license shall be as follows:**
- 1. Study and survey License
- 2. Generation License
- 3. Transmission License
- 4. Distribution License

No license shall be required for hydropower project up to a capacity of 1 one MW. Such hydropower project shall be registered with the District Water Resources Committee prior to commencement of the works of such project. Information of such registration shall be given to the Department of Electricity Development.

Hydropower Development Policy 1992 (Modified) 2001

- An application has to be duly submitted to the Department of Electricity Development (DoED) to obtain the license. The study/survey license of a hydropower project up to a maximum capacity of 10 MW shall be issued normally within 60 days of the submission of all the details.

- The licenses of all other types shall normally be issued within 120 days of the submission of all the details.

Hydropower Development Policy 1992 (Modified) 2001

- The survey and generation license has to be obtained for the captive plant. The license shall normally be issued within 120 days of the submission of all the details.

❑ **Term of the License:**

1. The study/survey license:

- The term of the study/survey license shall be for a maximum period of (5) five years.

Hydropower Development Policy 1992 (Modified) 2001

2. The hydropower generation license:

a) The project supplying the internal demand:

- Thirty-five years (35) from the date of issuance of the generation license.

b) The export-oriented hydropower project:

- Thirty years (30) from the date of issuance of the generation license.

3. The Electricity Transmission and Distribution License:

- The term of the electricity distribution license shall be twenty-five years (25) from the date of issuance of the license.
- The term of the license for electricity transmission and distribution may be renewed for ten years (10) at a time in accordance with the prevailing law.

Hydropower Development Policy 1992 (Modified) 2001

ii) Investment:

- Sole or JV investment of domestic and foreign investors
- Joint venture company of the private sector

Hydropower Development Policy 1992 (Modified) 2001

iii) Royalty:

Capacity	Capacity royalty per KW(till 15 yrs)	Energy royalty per KWh(till 15 yrs)	Capacity royalty per KW(beyond 15 yrs)	Energy royalty per KWh(beyond 15 yrs)
Less than 1 MW	NA	NA	NA	NA
1-10 MW	Rs 100	1.75%	Rs 1000	10%
10-100 MW	Rs 150	1.85%	Rs 1200	10%
More than 100 MW	Rs 200	2.00%	Rs 1500	10%
Captive	Rs 1500	NA	Rs 3000	NA
Export RoR	Rs 400	7.55%	Rs 1800	12%
Export Storage	Rs 500	10%	Rs 2000	15%

Hydropower Development Policy 1992 (Modified) 2001

iv) Power Purchase Agreement:

Reservoir Projects: Rs. 12.40 per unit (Dec-1 to may 28)

Rs. 7.1 per unit (May29 to Nov 30)

ROR Projects: Rs. 4.8 per unit (Wet Seasons) Jun to Nov

Rs. 8.4 per unit (Dry Seasons) Dec-May

Peaking ROR Projects: Rs. 4.4 per unit (Wet Seasons) Jun to Nov

Rs. 10.55 per unit (Dry Seasons) Dec-May

Department of Electricity Development (DoED)

- Electricity Development Center (EDC) was established on July 16, 1993 (2050 Shrawan 1) under the Ministry of Water Resources
- Objective is to develop and promote electricity sector and to improve financial effectiveness of this sector at the national level by attracting private sector investment
- EDC was later renamed as Department of Electricity Development (DOED) on January 26, 2000 (2056 Magh 12).

Department of Electricity Development (DoED)

- Promotion of private sector by awarding license for power generation
- Feasibility study of small, medium, large and storage type hydropower projects
- Monitoring of existing and under construction hydropower projects
- Advising MoE regarding plans and policies and other regulatory issues related to hydropower projects

Water and Energy Commission Secretariat (WECS)

- An advisory think tank type of body under the Ministry of Energy to advise to the government regarding water and energy related issues(irrigation, flood control, energy etc.).

(WECS) OBJECTIVES

- To formulate and assist in developing policies and strategies in the water resources and energy sector.
- To provide suggestions, recommendations and guidance in the development of irrigation, hydropower, and drinking water projects
- To formulate and develop policies and plans related to industrial use of water, flood management, in-land navigation, fisheries and other sectors related with water resources, along with the protection of the environment relating to the above sectors.

(WECS) OBJECTIVES

- To render opinion, advice and recommendations on bilateral and multilateral issues relating to water resources and energy.
- To act as a documentation center for all regional water resources and energy related issues.
- To provide assistance to the concerned ministries in formulating policies and objectives to be included in the perspective/periodic plan relating to the water resources and energy sector.

Foreign Investment and Technology Transfer Act,2049 (1992)

Main provisions:

i) Permission to be taken:

- Permission of the department of industries or department of cottage and small industries

ii) Facilities to foreign investors:

- Income tax facilities, taking foreign currency away from the country etc.

iii) Visa provision:

- Matters related to the non tourist visa, business visa, residential visa etc.

Iv Place of settlement of disputes:

v) Power to frame rules.

Water resources act, 2049

Main provisions:

i) Ownership of the Resources:

- State's ownership

ii) Utilization of Particular resources:

- License required except for drinking water, domestic use, irrigation, water mills, boat for local transport etc.

iii) Priority order:

a) drinking water and domestic use
b) irrigation
c) agriculture uses such as animal husbandry and fisheries
d) hydroelectricity
e) cottage industry, industrial enterprises and mining uses
f) recreational uses
h) other uses

Water resources act, 2049

Main provisions:

iv) License:

- Shall be issued within 60 days of applying with prescribed forms and documents

v) Government of Nepal may utilize or develop water resources:

vi) To enter into other's premises:

- Prior notice is necessary

vii) Not to cause substantial adverse effect on environment:

Water resources act, 2049

Main provisions:

viii)Water resources not to be polluted:

- Pollution tolerance limit fixed by Government shall not be violated.

ix) License may be cancelled:

- Cancellation of license in case the licensee acts or performs in contrary to this act or makes no progress

x) Penalties:

- Upto 5000/- if one violates the law.

Electricity Act, 2049

Main provisions:

i) Survey,generation, transmission or distribution of electricity:

- No license is required upto 1000 KW. But information should be furnished to DoED before execution

ii) Provision of license:

- Application in the prescribed form is needed along with technical, financial and environmental details.

iii) Terms of License:

- Maximum upto five years

iv) Restriction on the issuance of license:

- Same license will not be issued for other applicant

Electricity Act, 2049

Main provisions:

v) The government may enter into agreement with the license:

- Government of Nepal may enter into agreement of electricity or other financial and technical matters.

vi) Royalty to be paid.

vii) Facilities related to income tax, other taxes and charges.

viii) Facilities related to foreign exchange.

ix) Assessment of electricity charge and other charges.

Electricity Act, 2049

Main provisions:

x) National transmission line or grid.

xi) Sale of electricity to other utility.

xii) Import and export of electricity.

xiii) Quality standard of electricity.

xiv) Repair and maintenance.

xv) Condition of Nationalization

Electricity Act, 2049

Main provisions:

Provisions related to distributors and consumers of electricity:

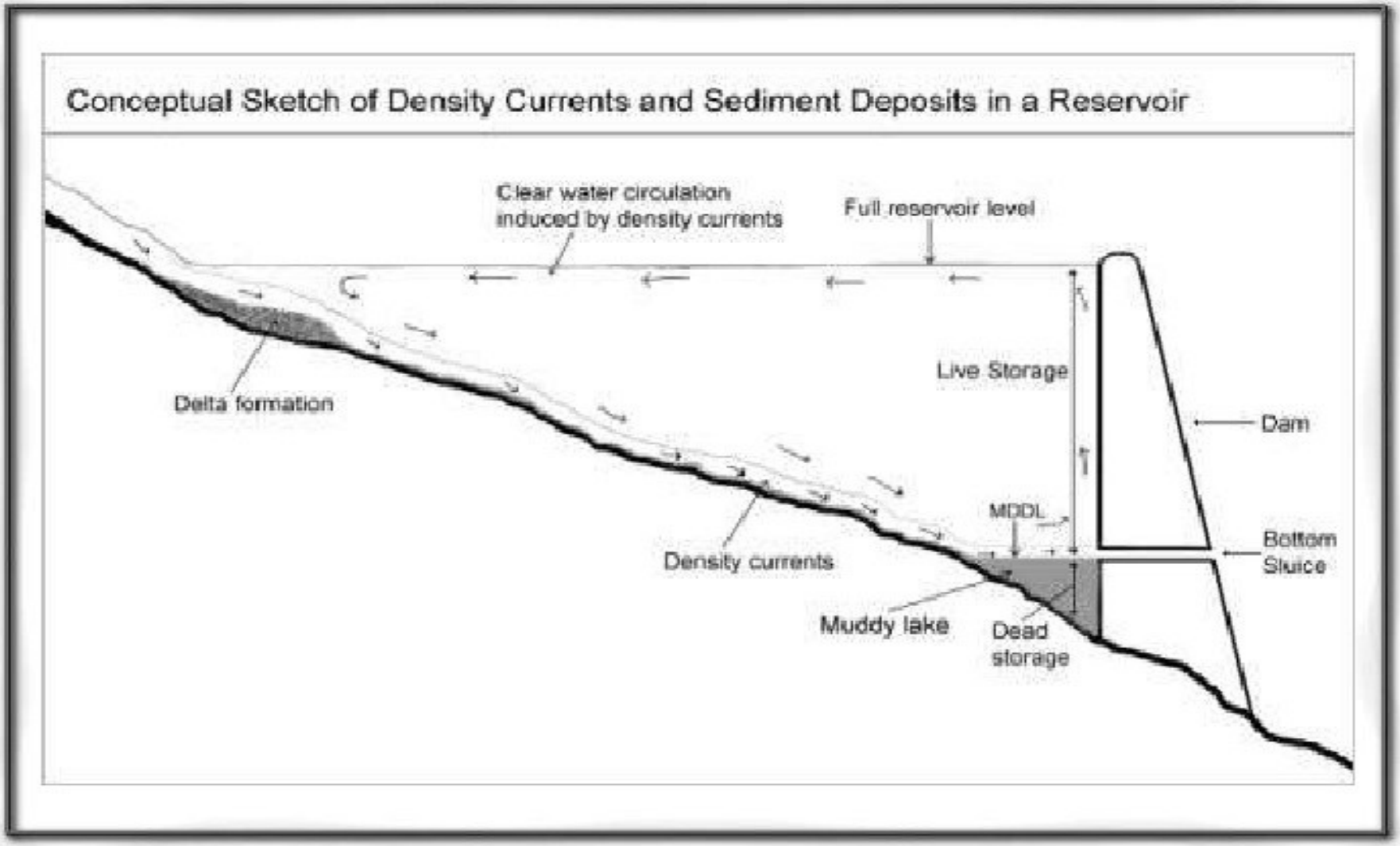
- Application to be submitted for the installation of electricity lines.
- Installation of meters by distributors.
- Quality of electricity to be maintained by the distributors.
- Optimum power factor to be maintained.
- Reactive power compensation.
- Clearance (both line and ground, house, etc.)
- Permitted distance between lines for different voltage levels.
- Safety from lightening.
- Earthing.
- No bare line above home

Electricity Act, 2049

Main provisions:

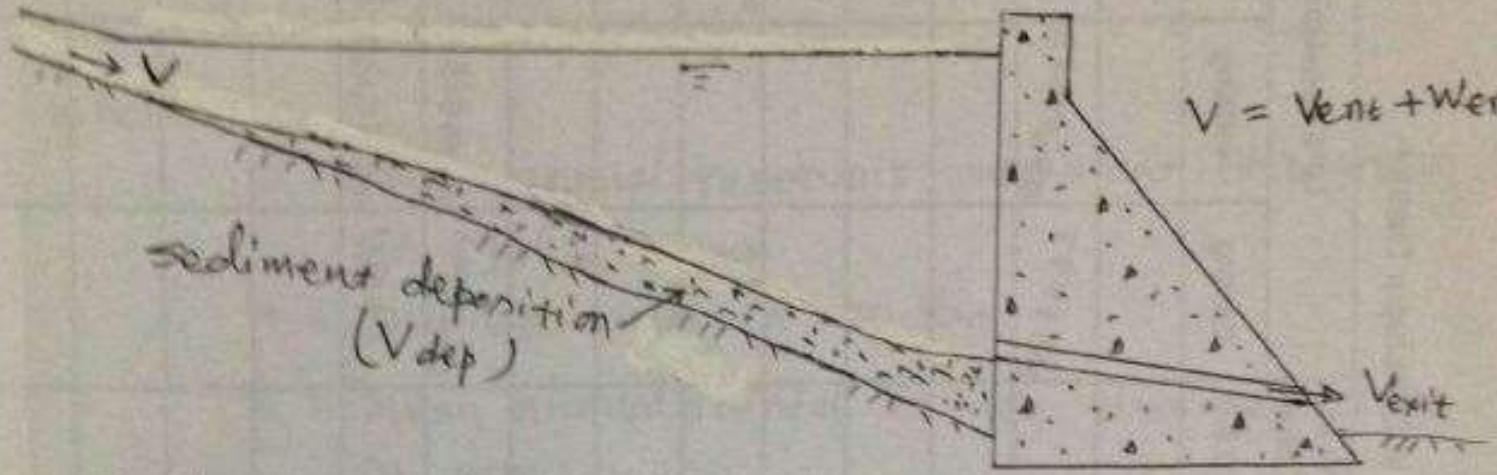
v) Provisions related to safety:

- Warning board.
- Insulation gloves.
- Notice for the first aid when affected by electric shock.
- Safety belt.
- Information of accident.


Conceptual Sketch of Density Currents and Sediment Deposits in a Reservoir
Clear water circulation induced by density currents
Full reservoir level
Live Storage
Delta formation
Dam
MDDL
Bottom Sluice
Density currents
Muddy lake
Dead storage

Reservoir sedimentation:

The deposition of sediment carried by river in the reservoir is known as reservoir sedimentation or reservoir silting.



- Sediment concentration of Yellow river ≈ 1600 gm/lit.
- " " " many Asian rivers ≈ 500 mg/lit. (ppm)

Sediment load consists of
i) suspended load, and
ii) Bed load.

i) suspended load:

The suspended load is very fine and generally kept in suspension because of vertical component of the eddies formed due to friction of flowing water against the bed. The suspended load is classified in terms of sediment diameter into three grades;

- Coarse sediments → particles > 0.20 mm
- Medium " → " 0.20 to 0.075 mm
- Fine " → " < 0.075 mm

ii) Bed load:

Bed load denotes the particles moving on or near the bed. Movement of particles takes place by rolling, sliding and hopping depending on the velocity of flow.

Factors affecting sedimentation:

i) Nature of soil of the catchment area:
- If the soil is soft, there is possibility of sheet erosion. Hard soil carry lesser silt.

ii) Topography of the catchment area:
- Steep slopes give rise to high velocities and erode the surface soil.

iii) Vegetation cover:
- Sufficient vegetation catchment area checks velocities and reduces erosion.

iv) Intensity of rainfall:
- Higher rainfall intensity causes greater runoff and more erosion.

Sediment control in Reservoirs:

1. Pre-constructing measures:
   - Selection of dam site in such a way as to exclude the runoff from the easily erodible catchment.
   - Construction of the dam in stages
   - Construction of check dams across the river streams contributing major sediment load.
   - Promotion of vegetation growth at the entrance of the reservoir as well as in the catchment.
   - Construction of under-sluices in the dam.
2. Post-constructing measures:
   - Removal of post flood water
   - Mechanical stirring of the sediment
   - Erosion control and soil conservation.

Life of a reservoir:

The term life of reservoir denotes the period during which whole or specified fraction of its total or active capacity is lost.

i) Service life of reservoir:

It is the period for which a reservoir is expected to provide a part of full planned benefits inspite of sedimentation.

ii) Economic life of reservoir:

It is a period for which benefits likely to accure in further operation of the reservoir with the further costs involved in the operation and maintenance of the system but excluding any element to cover the past costs incurred.

sediment yield of reservoir

→ sediment produced by erosion, landslide from a catchment may not always reach at the point of measurement or the dam of reservoir.

→ some part of sediment may be deposited en-route because of reduction in velocity & turbulence.

→ sediment yield = Gross sediment yield
- sediment quantity retained en-route.

→ That means the sediment yield is the amount of sediment that reaches the reservoir.

→ It depends upon the u/s catchment topography

Trap efficiency (η):

It is the percentage of sediment deposited in the reservoir even inspite of taking precautions and measures to control its deposition.

$$\eta = \frac{\text{Total sediment deposited in the reservoir}}{\text{Total sediment flowing in the river}}$$

- Most of the reservoirs trap 95 to 100% of sediment load flowing into them.
- It has not possible to reduce trap efficiency below 90% or so.

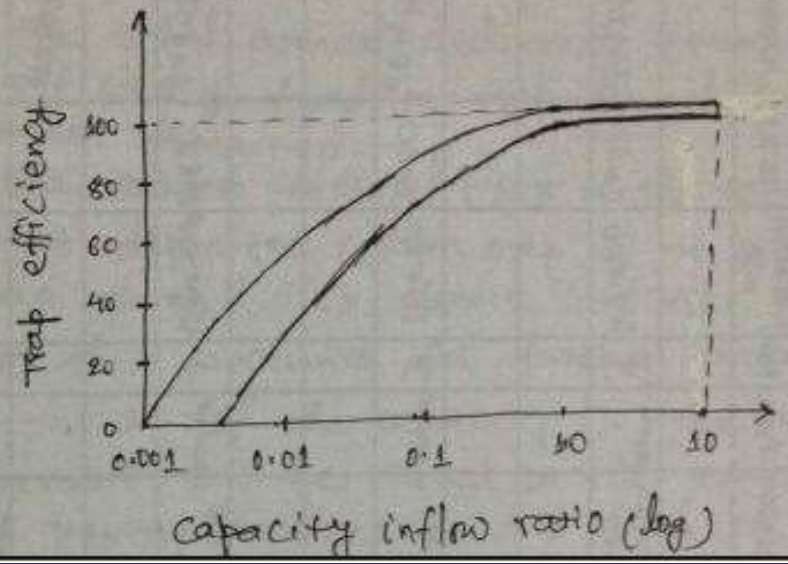
Capacity inflow ratio:

It is the ratio of the reservoir capacity to the total inflow of water in it.

i.e, Capacity Inflow ratio = $\frac{\text{Capacity}}{\text{Inflow}}$

It has found that the trap efficiency is the function of capacity inflow ratio.

$$\eta = f\left(\frac{\text{capacity}}{\text{Inflow}}\right)$$



- If capacity reduces with constant inflow, trap efficiency reduces; lesser sediment is trapped.
- For small reservoirs on large rivers, the trap efficiency is extremely low.
- For large reservoirs on small rivers, almost complete deposition of sediment may take place.

Measurement of sediment load – sediment sample to be collected at regular intervals of ime and at different depths of the reservoir. The sample are to be dried and the amount of sediment material is calculated. It is calculated as ppm or weight percentage.

Resevoir life – It is dependent on the maintenance of the reservoir and the amount of siltattion taking place at every flood season. A dead storage in the reservoir is provided for silting the fine materials. The water in the dead storage is unutilized. If proper care is not taken in the maintenance of the reservoir i.e ., desilting then the effective storage or live storage will be affected leading to failure of the reservoir or reducing the effective or live storage of the reservoir.

Trap efficiency (η) – This is a measure of reservoir sedimentation.
The investigations show that the trap efficiency is a function of the ratio of reservoir capacity to the total inflow

$$\eta = f\left(\frac{Capacity}{Inflow}\right)$$

The rate of silting is much higher in the initial stages of the inflow into the reservoir, then the rate of silting will reduces as silting goes on. Therefore the complete filling of reservoir may take quite a long period.
with regards to the small reservoir on a large stream

A small reservoir on a large dam having a small capacity has a large inflow rates.

It has a small capacity/inflow ratio.

The trap efficiency of such reservoirs is extremely small and the stream passes most of its inflow quickly and the finer sediments are discharged without getting time to settle.

On the contrary A large reservoir on a small stream with less inflow rates has higher capacity/inflow ratio.

Such reservoirs has a greater trap efficiency.

Such reservoirs retain water for several years and permit almost complete deposition of the sediment.

Life of a reservoir

1. Capacity of reservoir – is calculated from the study of inflow rates, leakage factors, type of rocks and structure, topography, drainage basin analysis and trap efficiency etc.

2. Assume 10 % trap efficiency for reduced capacity due to silting.

3. For the interval of 10 % capacity, average trap efficiency is calculated by taking the average of trap efficiency (η).

4. Sediment inflow rate is determined by drying the sediments from the water samples.

5. The total annual sediment transported is multiplied by the trap efficiency and is converted into hectare-metre (volumetric) units for one year.

6. Volume interval (10 % of the capacity) is divided by the sediment deposited in order to get number of years to fill this volume interval of 10 % capacity.

7. This procedure is repeated further at 80 %, 70 %, 60 %,..... 20 % of the capcity. The total life of the reservoir = total number of years required to fill each of the volume intervals.

Reservoir Sediment Control

1. Proper selection of reservoir site
2. Control of sediment Inflow
3. Proper designing and reservoir planning
4. Control of sediment deposit in the reservoir
5. Removal of sediment deposit
6. Erosion control in the catchment area

Flow Duration Curve

Flow duration curve is a plot of discharge versus percentage of time that a particular discharge was equated or exceeded. The basic time unit used in preparing a flow duration curve will greatly affect its appearance. For most studies, mean daily discharges are used. These will give steep curve when mean monthly flow is used, resulting curve will be flatter due to averaging of short term peaks with intervening short term flows during a month.

Steps

Step 1

Sort (rank) average daily discharges for period of record from the largest value to the smallest value, involving a total of N values

Step 2

Assign each discharge value a rank (n), starting with 1 for the largest daily discharge value.

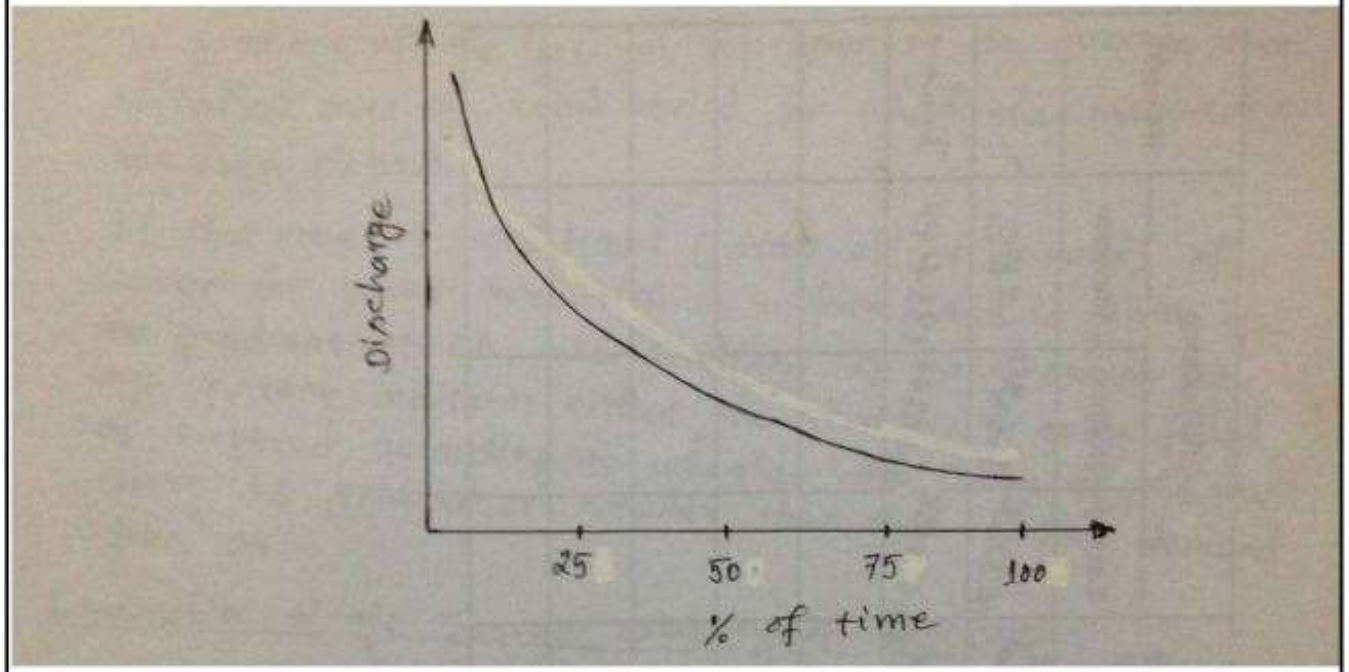
Step 3

Calculate exceedance probability (P) as follows;

$$P = \frac{n}{N} \times 100$$

Step 4

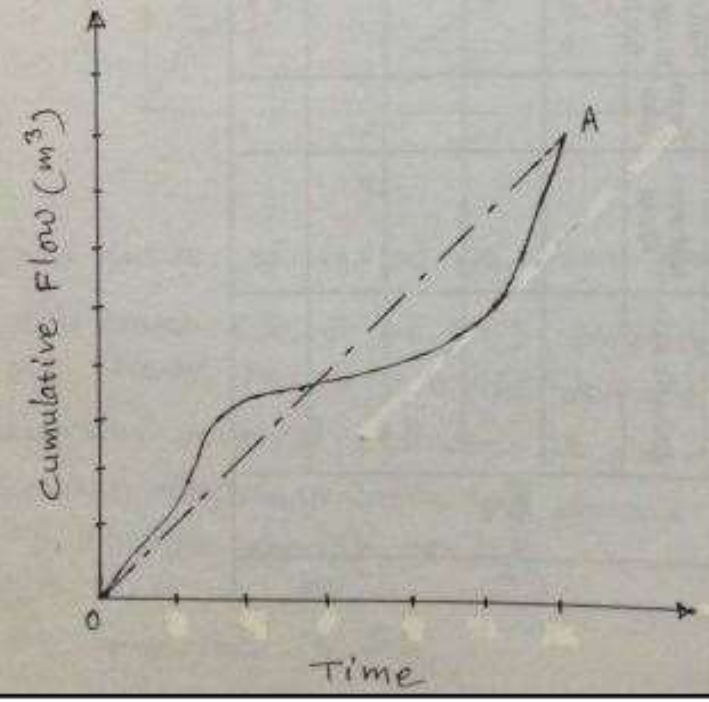
Plot probability of exceedance versus discharge curve.


Discharge
25
50
75
100
% of time

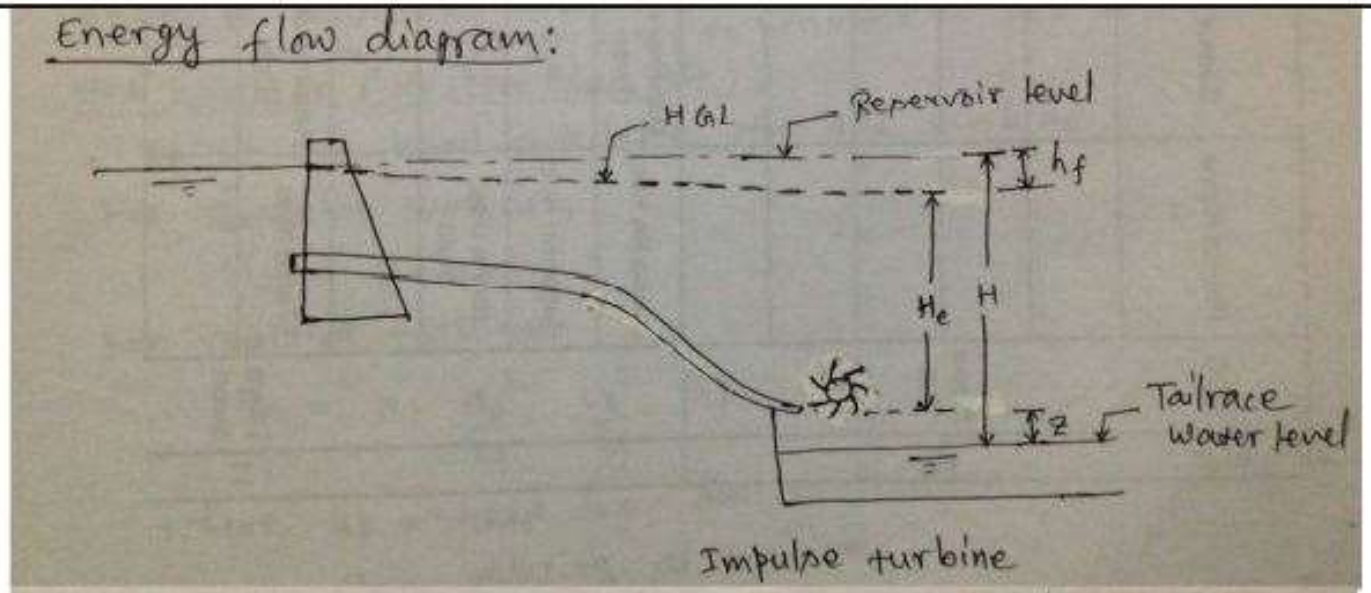
Mass curve or Ripple diagram:

The mass curve is a plot of cumulative flow (volume) against time throughout the period of record.

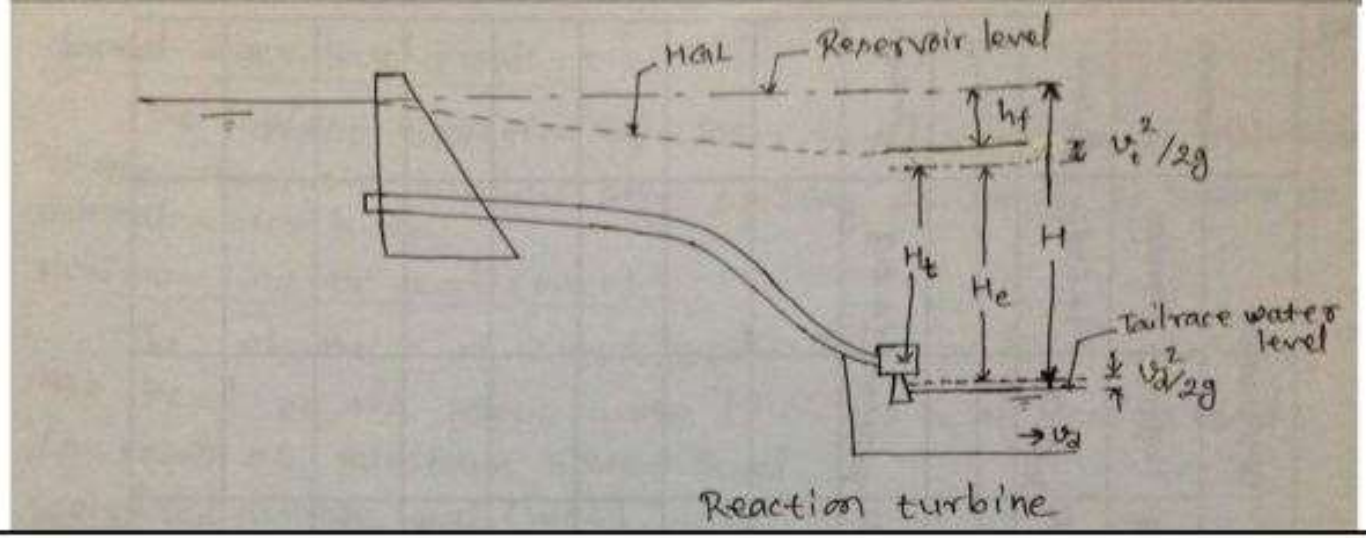
It is useful tool in calculating the storage capacity of the reservoir and safe yield from a reservoir of given capacity. The slope of the curve at any point indicates the rate of inflow at that particular time.



Energy flow diagram:



Impulse turbine



Reaction turbine

Net head or Effective head (He):

It is the head available for the turbine.

For impulse turbine,

$$He = H - z - h_f$$

For reaction turbine,

$$He = H - \frac{v_d^2}{2g} - \frac{v_t^2}{2g} - h_f$$

where, h_f = head loss due to friction

v_t = velocity at turbine

and v_d = exit velocity

3.4 POWER DURATION CURVE

It is a plot of power vs. percentage of time, we have,

$$\text{Power } (P) = \eta\gamma Q H_{net}$$

where, $\gamma = 9810 N/m^3$

η is overall efficiency

Q is discharge at turbine

H_{net} is net head $= H_{Gross} - h_f$(head loss)

$$\text{Friction head loss } (h_f) = \frac{flv^2}{2gd}$$

where, f is friction factor

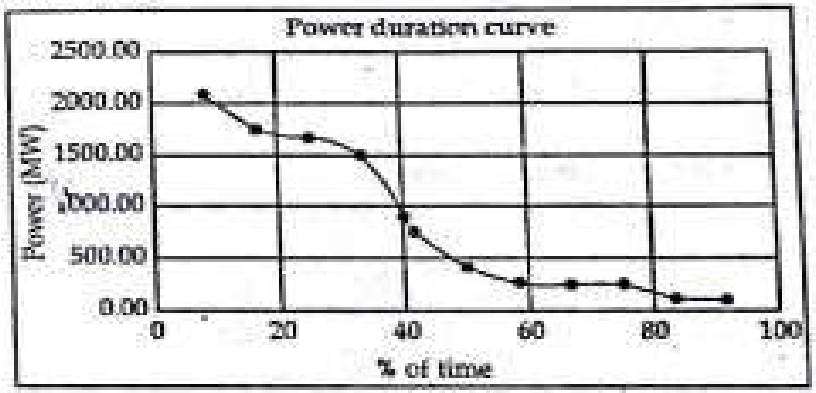
l is length of pipe

v is velocity of water

d is diameter of pipe

Considering net head remains constant,

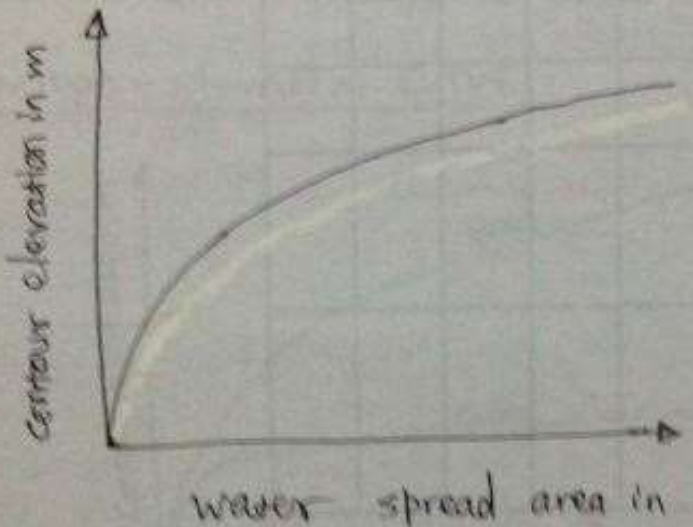
$$P = \text{Constant} \times Q$$



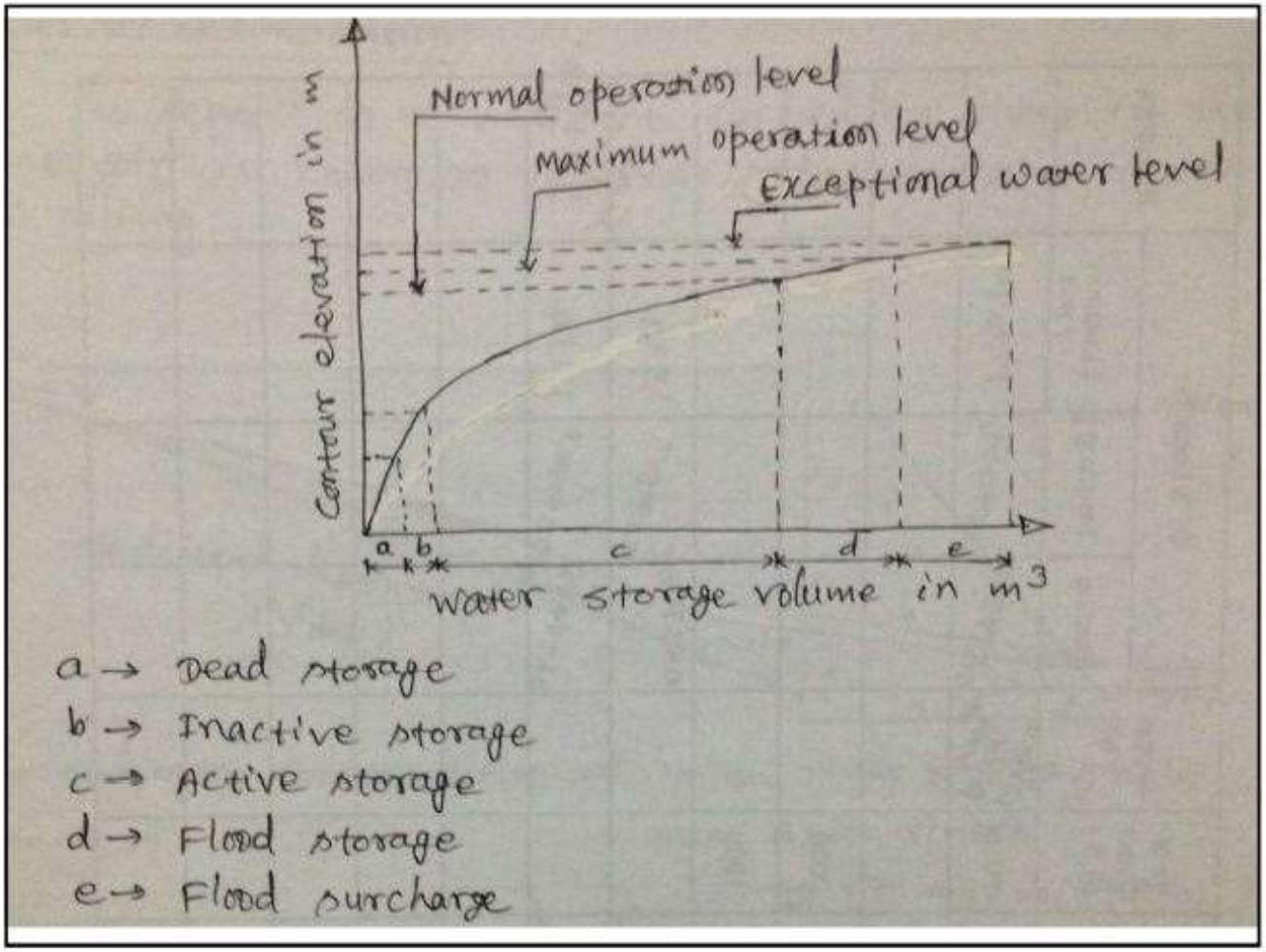
Hence, power duration curve is similar to the flow duration curve. The produce to draw power duration curve is similar to power duration curve except we should determine the mean monthly power.

Area - Elevation curve and Storage - Elevation curve:

Area-elevation curve also called water spread area curve is a plot of contour elevation against water spread area.



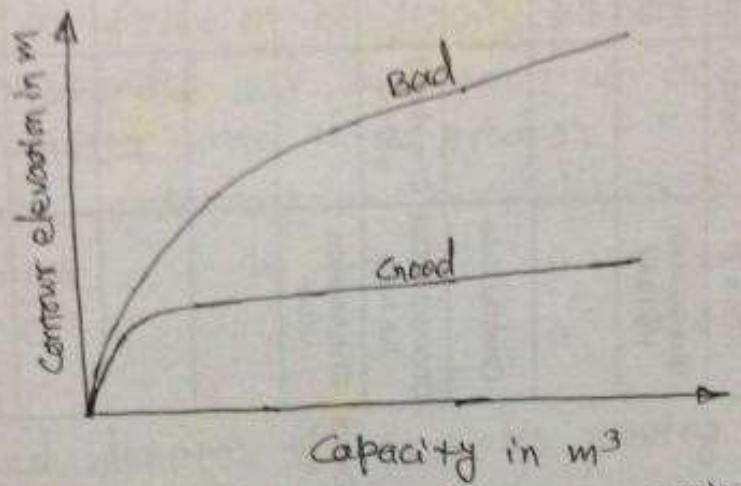
Storage elevation curve also called capacity-elevation curve or capacity curve is a plot of contour elevation against water storage volume.



a → Dead storage
b → Inactive storage
c → Active storage
d → Flood storage
e → Flood surcharge

* Area-elevation curve determines the water spread area corresponding to known reservoir level.
* Storage- elevation curve determines reservoir storage volume corresponding to know reservoir level.

Best storage - elevation curve:



The best capacity curve for a reservoir is the one in which the rise to the straight line is the quickest. It results from a cup-shaped catchment, with gentle longitudinal slope.

The long term mean monthly flow of a stream is show in table below;

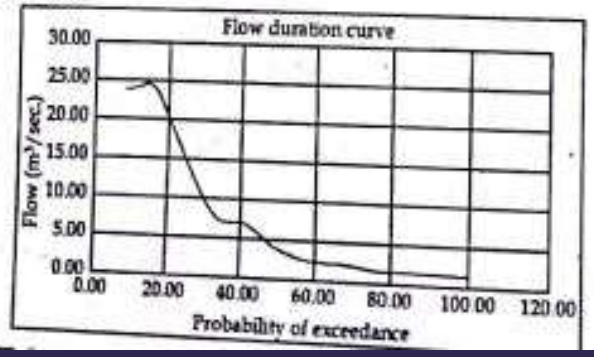
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	De
Flow $m^3/sec.$	1.59	1.35	1.27	1.51	2.28	7.53	23.76	23.80	14.56	6.86	3.72	2.3

Plot the flow duration curve.

Solution:

Month	Flow (m^3/sec)	Flow in descending order	Rank (n)	Probability of exceedance $P = \frac{n}{N} \times 100$
Jan	1.59	23.80	1	8.33
Feb	1.35	23.76	2	16.67
March	1.27	14.56	3	25.00
April	1.51	7.53	4	33.33
May	2.28	6.86	5	41.67
June	7.53	3.72	6	50.00
July	23.76	2.28	7	58.33
Aug	23.80	2.23	8	66.67
Sept	14.56	1.59	9	75.00
Oct	6.86	1.51	10	83.33
Nov	3.72	1.35	11	91.67
Dec	2.23	1.27	12 (N)	100

Probability of exceedance is plotted in x-axis and flow is plotted in y-axis to g
flow duration curve.



Q. The avg. long term monthly flows (m^3/s) of a river from Jan to Dec are found to be 4.0, 3.5, 3.4, 5.2, 9.8, 23, 17.5, 33, x, 7.6 and 5.5 respectively. The gross head, conveyance eff and electro mechanical eff of a proposed run off river type hydel plant are 125m, 85% and 80% respectively. and can be assumed to be constant for all flow season. The design discharge of the plant has been set @75 and the minimum dis release in the river is to be $0.3 m^3/s$. Based on the data, answer the following:

(i) what is design discharge?
(ii) what is installed capacity?
(iii) what is firm power and annual firm energy?
(iv) what is secondary energy?
(v) what is the required storage capacity of a reservoir to operate the plant at the installed capacity throughout the year?

Sol?

⟹ Gross head = 125m

net head = conv. eff * Gross head

= 0.85 x 125

Sol?

⇒ Gross head = 125m

net head = conv. eff * Gross head

= 0.85 x 125

electromeghanical eff. (η_e) = 0.8

d/s release = 0.3 m^3/s.

S.N.	Q in decreasing order	rank (m)	%
1	55	1	$\frac{1}{12} \times 100\% = 8.33\%$
2	47	2	$\frac{2}{12} \times 100\% = 16.67\%$
3	33	3	$\frac{3}{12} \times 100\% = 25\%$
4	23	4	$\frac{4}{12} \times 100\% = 33.33\%$
5	~~9.8~~ 15	5	41.67%
6	9.8	6	50%
7	7.6	7	58.33%
8	5.5	8	66.67%
9	5.2	9	75%
10	4.0	10	83.33%
11	3.5	11	91.67%
12	3.4	12	100%

n = 12

75

$\therefore Q_{75\%} = 5.2\ m^3/s$.

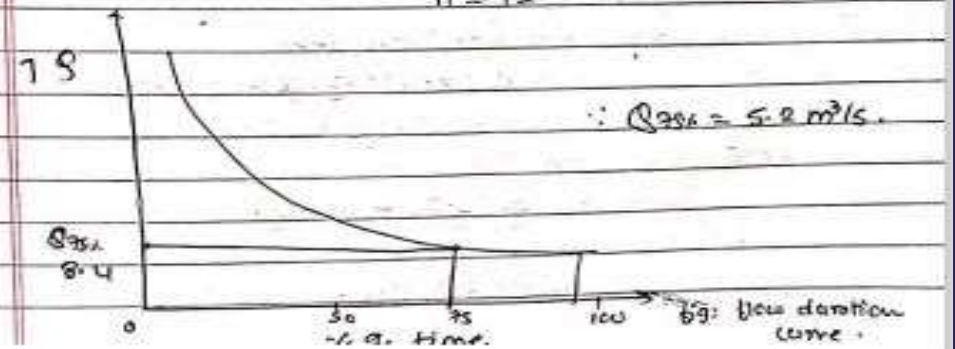


fig: flow duration curve.

①	②	③	④	⑤	⑥	⑦
month	Q(m^3/s)	d(s) release (m^3/s)	Available Q, (m^3/s)	Flow for power (m^3/s)	power (Kw)	Days
Jan	4.0	0.3	3.7	3.7	3085.25	31
Feb	3.5	0.3	3.2	3.2	2668.32	28
Mar	3.4	0.3	3.1	3.1	2584.94	31
Apr	5.2	0.3	4.9	4.9	4085.87	30
May	9.8	0.3	9.5	5.2	4336.02	31
Jun	23.0	0.3	22.7	5.2	1336.02	24
July	47.0	0.3	46.7	5.2	"	31
Aug	55.0	0.3	54.7	5.2	"	31
Sep	33.0	0.3	32.7	5.2	"	30
Oct	15.0	0.3	14.7	5.2	"	21
Nov	7.6	0.3	7.3	5.2	"	30
Dec	5.5	0.3	5.2	5.2	"	31

col 4 = col 2 - col 3.

col 6 = $\eta_o \cdot \rho_w \cdot Q \cdot h_u$.

For Jan: $P = \eta_o \cdot \rho_w \cdot Q_d \cdot h_u$

$= 0.8 \times 9.81 \times 3.7 \times 106.25$

$= 3085.25$ KW.

col 8 for Jan.

$= \frac{3085.25 \times 31 \times 24}{10^6}$

$= 2.3$ Gwh.

@ Note: In Nepal = 10% dry months i.e 10% of min flow of the classmate year.

⑧ Energy (GWh)	⑨ Deficit @ to run plant at instant capacity (m^3/s)	⑩ Deficit vol. (Mm^3)	⑪ Secondary energy (GWh)
0.3	-1.5	-4.02	0.5
1.79	-2.0	-4.84	0
1.92	-2.1	-5.62	0.13
2.04	-0.3	-0.79	1.15
3.23	0	0	1.03
3.12	0	0	1.23
3.23	0	0	1.03
3.23	0	0	1.03
3.12	0	0	1.33
3.23	0	0	1.03
3.12	0	0	1.33
3.23	0	0	1.03
		$\Sigma = -15.26$	$\Sigma = 12.95$

for Jan = 2.3 - 1.79 = 0.51

Col.9 = -5.2 + Col.5.

Col.10 = Col.9 × (Col.7 × 24 × 3600) / 10^6 = − Mm^3

for Jan = $\frac{-1.5 \times 31 \times 24 \times 3600}{10^6}$ = -4.02 (-ve is due to deficit.)

Col.11 = Col.8 − minimum Energy
= Col.8 − 1.79.

① ∴ Design discharge (Q_{design}) = 5.2 m^3/s.

② Firm power/min power (P) = 2584.94 KW

③ Firm energy (E) = 1.79 GWh × 12 = 21.48 GWh (annual, min)

④ Secondary energy = 12.93 GWh.

⑤ Installed capacity of the plant = 4336.02 KW

⑥ Reservoir capacity = 15.26 Mm^3.

A hydropower plant is to be planned in a Nepalese river, wh
mean monthly flows for a typical year are as follows:

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov
Q(m^3/sec.)	4.4	3.9	3.4	4.2	5.6	16.5	78.1	108.9	52.8	22.0	9.9

Other data pertaining to the plan are as follows;

- Design discharge = 18 m^3/sec.
- Full supply level = 2250 masl
- Turbine centre line = 1650 masl
- Diameter of 4.0 km long tunnel = 3.0 m, f = 0.014
- Diameter of 1 km long penstock = 2.2 m, f = 0.012

Hydraulic efficiency 95%, Transformer efficiency 99%, cons
only frictional loss

a) Compute installed capacity, primary and secondary energ
produced from the power plant assuming that 10% m
flow to release downstream. What is plant factor?

b) The developer is interested to develop a daily peaking p
for 4 hours. What will be the capacity of the reservoir is
daily peaking requirement. [2072 (

Solution:

Design discharge (Q) = 18 m^3/sec.

Gross head = 2250 − 1650 = 600 m

Friction head loss in tunnel = $\frac{flv^2}{2gD}$

$$= \frac{flQ^2}{2gD\left(\frac{\pi D^2}{4}\right)^2} = \frac{8flQ^2}{g\pi^2 D^5}$$

$$= \frac{8 \times 0.014 \times 4000 Q^2}{9.81 \times \pi^2 \times 3^5}$$

$$= 0.019\, Q^2$$

Friction head loss in penstock = $\frac{8 \times 0.012 \times 1000 Q^2}{9.81 \times \pi^2 \times 2.2^5} = 0.0192\, Q^2$

Total head loss = $0.019\, Q^2 + 0.0192\, Q^2 = 0.0382\, Q^2$

Overall efficiency = 0.95 × 0.93 × 0.99 = 0.87

Environmental release = 10% of 3.4 = 0.34 m^3/sec.

Month	River Discharge	Available Discharge	Design Discharge	Head Loss	Net Head	Power (KW)	Days	Energy (GWh)
Jan.	4.4	4.06	4.06	0.630	599.370	20768.71	31	15.45
Feb.	3.9	3.56	3.56	0.484	599.516	18215.41	28	12.24
Mar.	3.4	3.06	3.06	0.358	599.642	15660.37	31	11.65
Apr.	4.2	3.86	3.86	0.569	599.431	19747.61	30	14.22
May	5.6	5.26	5.26	1.057	598.943	26888.07	31	20.00
Jun.	16.5	16.16	16.16	9.976	590.024	81376.59	30	58.59
Jul.	78.1	77.76	18.00	12.377	587.623	90273	31	67.16
Aug.	108.9	108.56	18.00	12.377	587.623	90273	31	67.16
sep.	52.8	52.46	18.00	12.377	587.623	90273	30	65.00
Oct.	22	21.66	18.00	12.377	587.623	90273	31	67.16
Nov.	9.9	9.56	9.56	3.491	596.509	48670.18	30	35.04
Dec.	6.4	6.06	6.06	1.403	598.597	30959.61	31	23.03
							Total	456.72

Installed capacity = 90273 kW

Total energy = 456.72 GWh

$$\text{Primary energy} = 15660.37 \times 365 \times \frac{24}{10^6} = 137.18 \text{ GWh}$$

Secondary energy = 456.72 − 137.18 = 319.54 GWh

$$\text{Plant factor} = \frac{\text{Actual energy produced by plant}}{\text{Maximum energy that can be produced}}$$

$$= \frac{456.72 \times 10^6}{90273 \times 365 \times 24} = 0.577$$

Design discharge = 18 m^3/sec.

Water stored during off peaking hour *i.e.*, 20 hours = 18 × 20 × 60 × 60

= 1296000 m^3

Determine requirement reservoir capacity from the data given below;

Months	Jul	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun
Mean monthly flow (m^3/sec.)	30	33	35	30	29	20	15	13	10	8	7	15
Rainfall (cm)	28	30	34	8	0	0	0	0	4	6	10	16
E_s (cm)	10	7	6	9	5	4	4	5	10	10	12	13
Demand (ha-m)	1500	2000	2700	4000	4800	4800	4600	4500	4500	2700	2500	1500

Assume that surface area of reservoir is 6000 hac throughout.

lution:

lculation procedure

For July,

$Q_0 = 30\ m^3/sec.$

Rainfall = 28 cm

Evapo-transpiration (E_0) = 10 cm

Discharge due to rainfall,

$$Q_{rainfall} = \frac{(28-10)\times 10^{-2} \times \text{Surface area}}{30 \times 24 \times 3600}$$

$$= \frac{(28-10)\times 10^{-2} \times 6000 \times 10^{4}}{30 \times 24 \times 3600}$$

$$= 4.167\ m^3/sec.$$

Total discharge (Q) = 30 + 4.16 = 34.167 $m^3/sec.$

Volume inflow in July (V_j) = Q × day × 24 × 3600

= 34.167 × 30 × 24 × 3600 = 88560000 m^3

milarly, calculated all months in the tabulation forms:

ence, required reservoir capacity is 63224000 m^3

Month	Mean monthly flow (m^3/sec.)	Rainfall (cm)	E_s (cm)	Q (rainfall) (Q_R)	Total Q = (Q_m + Q_R)	Mean monthly volume (m^3)	Demand (m^3) (D)	Surplus (m^3)	Deficit (m^3)
July	30	28	10	4.167	34.167	88560000	15000000	73360000	
Aug	33	30	7	5.324	38.324	99336000	20000000	79336000	
Sep	35	34	6	6.481	41.431	107520000	27000000	30520000	
Oct	30	8	9	−0.231	29.769	77160000	40000000	37160000	
Nov	29	0	5	−1.157	27.843	72168000	48000000	24168000	
Dec	20	0	4	−0.926	19.074	47440000	48000000	140000	
Jan	15	0	4	−0.926	14.074	36480000	46000000		9520000
Feb	13	0	5	−1.157	11.843	80696000	45000000		14304000
March	10	4	10	−1.389	8.611	22320000	45000000		229
April	8	6	10	−0.826	7.074	1836000	27000000		866
May	7	10	12	−0.463	6.537	16944000	25000000		305
June	15	16	13	0.694	15.694	40680000	15000000	25680000	
								Total deficit	6322

Hydropower plant developed in the river has net head of 110 m, overall efficiency of 85% and 10% of water is required to be le environment and downstream user in the river. If the plant is use peak, load plant operating only for 6 hours a day, determine the capacity of the plant.

Mean monthly flow for a Nepalese river is given below:

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov
Q(m^3/sec.)	100	120	140	300	350	1800	2000	2520	2000	900	650

i) Without pondage

ii) With pondage but allowing 10% of water to be lost in evapora

Solution:

Assume,

Stream discharge = Q_{min}

$Q_{min.} = 100\ m^3/sec.$

Q_{design} for power generation $= Q_{min} - 10\%$ of Q_{min}

$$= 100 - \frac{10}{100} \times 100$$

$$= 90\ m^3/sec.$$

Peak load plant operating time = 6 hours daily

Given that;

Net head (H_{net}) = 110 m

Efficiency (η) = 85% = 0.85

i) Without pondage

Firm capacity of the plant (P) = $\eta\gamma QH$

$$= 9.81 \times 10^{-3} \times 0.85 \times 90 \times 110$$

$$= 82.55\ MW$$

ii) With pondage

Operating time = 6 hours daily

Volume stored in 18 hrs = $90 \times 18 \times 3600 = 5832000\ m^3$

Evaporation volume (10%) = $583200\ m^3$

Total volume = $5248800\ m^3$

Additional flow $(Q_{Add}) = \frac{5248800}{6 \times 3600} = 243\ m^3/sec.$

Total flow (Q) = $90 + 243 = 333\ m^3/sec.$

Firm capacity (P) = $\eta\gamma QH$

$$= 9.81 \times 10^{-3} \times 0.85 \times 333 \times 110$$

$$= 305.44\ MW$$

Example 3.11.

A RoR plant for peak load demand of 8 hours a day has least amount inflow of 20 cumec with net head 25m. The plant efficiency can be taken as 85%. Determine

a) Firm power output of the plant without pondage and with pondage.

Take a water loss of 10% due to of evaporation.

Solution:

(i) Firm output without pondage

$= 9.81 \times 20 \times 25 \times 0.85 = 4.169 \times 10^3 \text{kW}$

(ii) With pondage; water stored in 16 hours when not in function. (24-8=16)

$= 20 \times 16 \times 60 \times 60 = 1.152 \times 10^6 \text{m}^3$

Net water obtainable from pondage when plant is working for 8 hours, allowing 10% losses

$= (1.152 \times 10^6) \times 0.9$

$= 1.037 \times 10^6 \text{m}^3$

Discharge available from pondage

$$= \frac{(1.038 \times 10^6)}{(8 \times 60 \times 60)}$$

$= 36$ cumecs

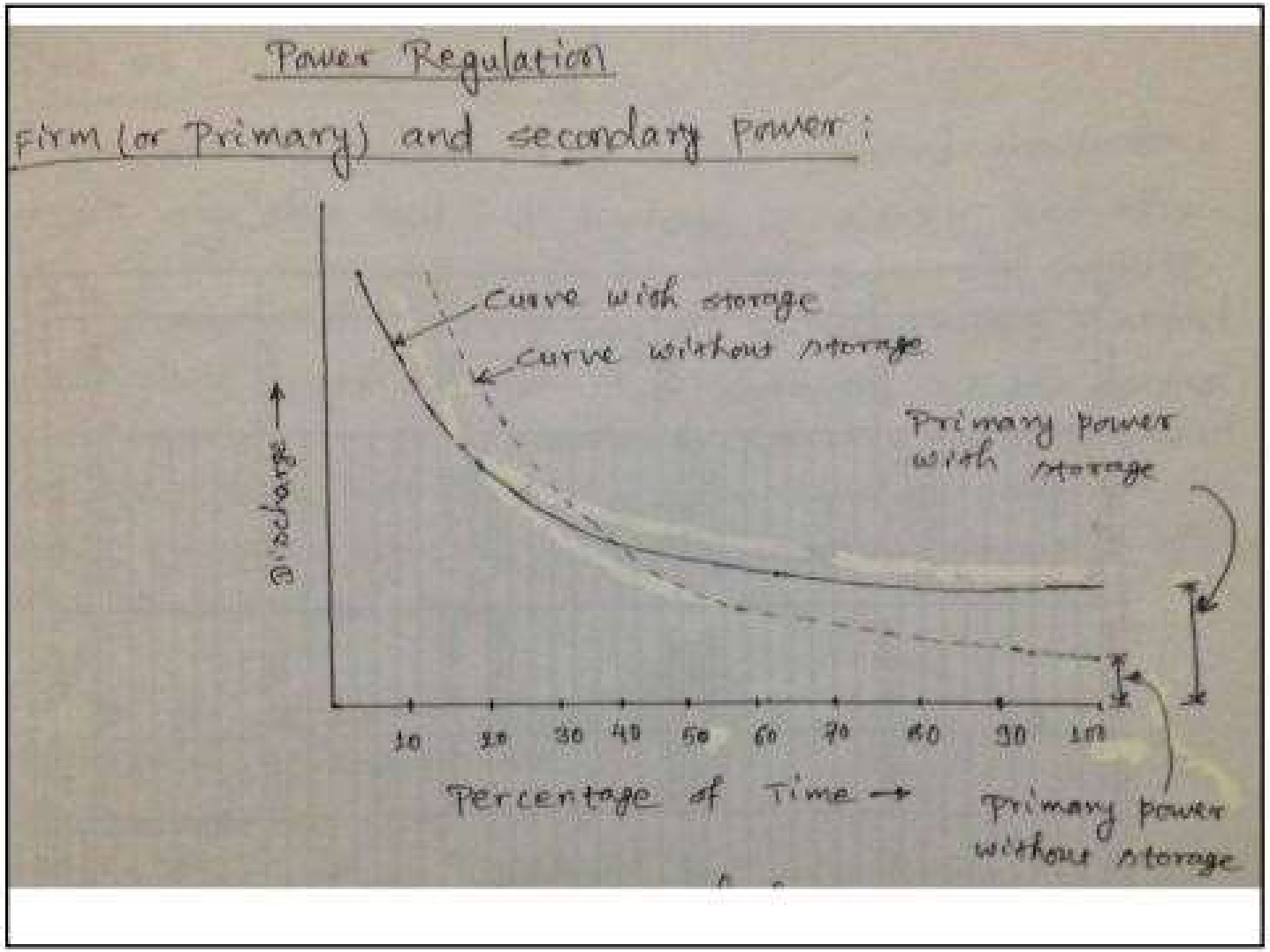
Firm power output of plant with pondage

$= 9.81 \times (20 + 36) \times 25 \times 0.85$

$= 11.674 \times 10^3 \text{kW}$

Power Regulation

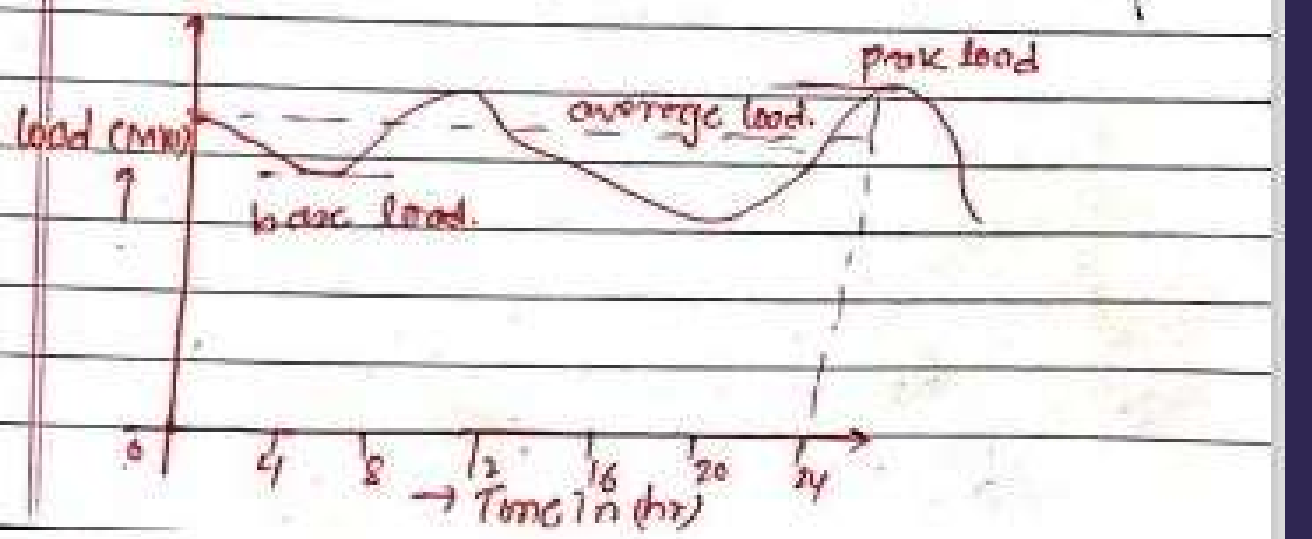
Firm (or Primary) and secondary power :



The firm power is the power which is available throughout the year. It corresponds to the minimum stream flow with or without consideration of storage system. After analysing hydrograph of a river for a series of year the discharge available for more than 95% of the time is determined. The power corresponding to this discharge is usually called firm power. Firm power can be increased by providing storage facility, as it flattens the flow duration curve. The unit price of the firm power is much higher than the secondary power.

The secondary power is the excess power, which is available in the plant exceeding the firm power. The secondary power is useful in an interconnected system of power plants. At off-peak hours, the secondary power may be called upon to relieve the inter-connected stations thus affecting economy.

11. load curve :- load curve is graph of load consumption with respect to any time. so this curve gives the indication of power used at any time. Generally load curve is daily load curve, weekly load curve, monthly load curve & yearly load curve.



* Peak load:- The highest demand in a day is called the peak load. the load is defined as that part of the load carried at intensity greater than 4/3 times the mean load intensity.

* Base load:- The load which is continuously carried during that time period. For daily load curve minimum load within a day is called base load for that particular day.

* Average load:- Average load is defined as the average consumption over a defined time period. Area under the load curve divided by time gives the average load

Average load:

It is the load produced per unit time.

In other words, it is the hypothetical constant load over a given period of time that would produce the same energy output as the actual loading produced.

Peak load or demand:

The highest instantaneous value of the demand is known as peak load or peak demand.

Load factor (LF)

It is the ratio of the average load over a certain period to the peak load during the same period.

$$\text{i.e, Load factor} = \frac{\text{Average load}}{\text{Maximum load}}$$

$$\text{Daily load factor} = \frac{\text{Average load during 24 hrs}}{\text{Maximum demand}}$$

$$= \frac{\text{Energy consumed during 24 hrs}}{(\text{Maximum demand}) * 24 \text{ hrs.}}$$

Annual load factor = $\frac{\text{Average load during 8760 hrs}}{\text{Maximum demand}}$

$= \frac{\text{Energy consumed during 8760 hrs}}{(\text{Maximum demand}) * 8760 \text{ hrs}}$

Capacity factor (CF) or Plant factor (PF) or Plant use factor:

It is the ratio of the average load to the plant capacity i.e, the ratio of the average output to the installed capacity of the power plant.

CF or PF = $\frac{\text{Average load}}{\text{plant capacity}}$ or $\frac{\text{Average output}}{\text{installed capacity}}$

- when maximum load = Plant capacity,
  Capacity factor = Load factor
- Range of PF = 0.25 to 0.75

Utilization factor (UF):

It is the ratio of quantity of water actually utilized for power production to that available in the river.

If the head is constant,

$$UF = \frac{\text{Power utilized}}{\text{Power available}}$$

- Range of UF = 0.4 to 0.9

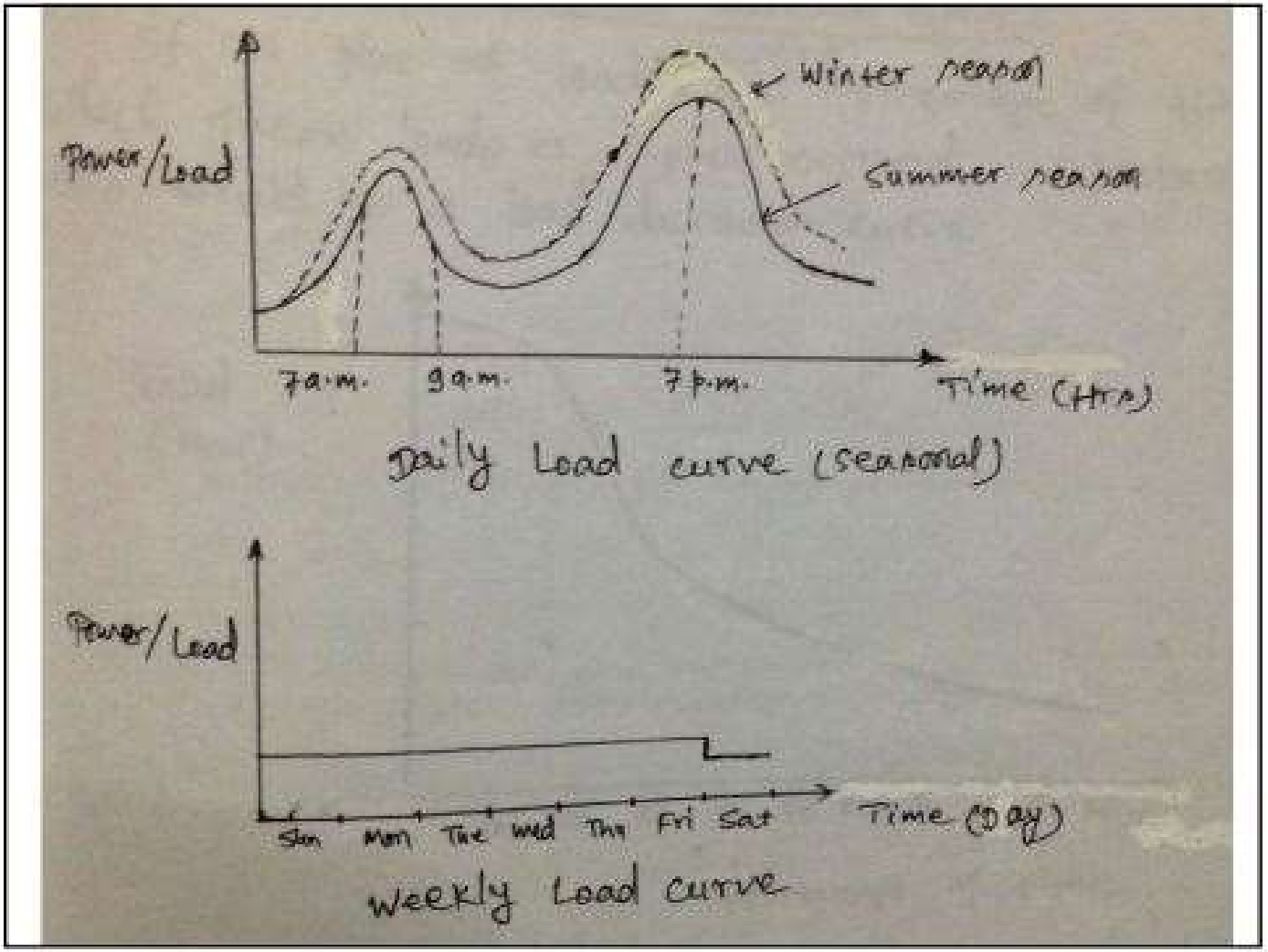
Diversity factor (DF):

It is the ratio of sum of maximum demands of the individual consumers to the simultaneous maximum demand of all the consumers during a particular time.

$$DF = \frac{\text{Sum of individual maximum demands}}{\text{Simultaneous maximum demand}}$$

Load curve / Power curve:

A load curve is a graph of load consumption with respect to time and directly gives an indication of the power used at any time.


Power/Load
Winter season
Summer season
7a.m.
9a.m.
7p.m.
Time (Hrs)
Daily Load curve (seasonal)
Power/Load
Sun
Mon
Tue
Wed
Thu
Fri
Sat
Time (Day)
Weekly Load curve

Tariff Structure

- Tariff structure is a set of rules and procedure that determine how to charge different categories of consumers.
- Types:

1. Flat rate tariff
2. Volumetric tariff: Based on actual metered consumption (with different variables; constant volumetric tariff, increasing block tariff, linear progression tariff & peak load tariff).
3. Multi-part tariff: It includes two part tariffs, where users pay both a monthly fee for access and a usage fee for consumption of electricity.

Tariff Structure

- An effective tariff structure needs to take into account the following elements:

a) Financial viability (ensuring that the maximum allowed revenue is covered)

b) Cost-reflectiveness (charging the customers in a way that reflects the costs plus a reasonable return a investment)

c) Efficiency (setting prices at marginal cost)

d) Social acceptability (ensuring that charges are reasonable so that all customers receive at least basic service and the subsidies are efficiency targeted.

Tariff Structure

- Tariff shall be fixed on the basis of:

1. Rate of depreciation
2. Reasonable profit
3. Mode of operation of plant
4. Changes in consumers price index
5. Marginal cost of electricity generation
6. Exchange rate of convertible foreign currency
7. Financial institutional providing loan
8. Royalty and policy adopted by Government of Nepal

INSTALLED CAPACITY OPTIMIZATION

The power generated by a hydropower plant is a function of head and discharge, which is given by the following equation:

$$P = \eta \gamma Q H$$

Where P =power, γ = specific weight of water, Q = discharge, H = Head, and η = overall efficiency

Energy = P*time

Revenue = Energy*rate

The power can be calculated for different percentile of available flow. Increasing the percentile of available flow, the design discharge reduces. Decreasing the design discharge, the size of hydropower components such as intake, settling basin, conveyance system, penstock etc. decreases. Hence, the project cost reduces. But, the project capacity as well as energy also reduces due to the decrease in design discharge, thereby decreasing annual revenue. Hence the revenue and cost is traded to get optimum benefit. For this generally, the flow with 25% available to 70% available with certain interval is calculated from the flow duration curve, and power and revenue is calculated. The cost for each option is also calculated and then optimization study is done. The optimum capacity is taken as installed capacity.

Power system and its components:

Power system is the system of such subsystems or components which generate electricity from the naturally available source of energy viz water and transmit it to the place of consumption safely and efficiently.

The power system is said to be composed of following three subsystems.

1. Generation system
2. Transmission system
3. Distribution system

1. Generation system:

It is the place from where electricity is tapped from the sources of energy available. It consists of turbines, generators and measuring, protecting and controlling equipments

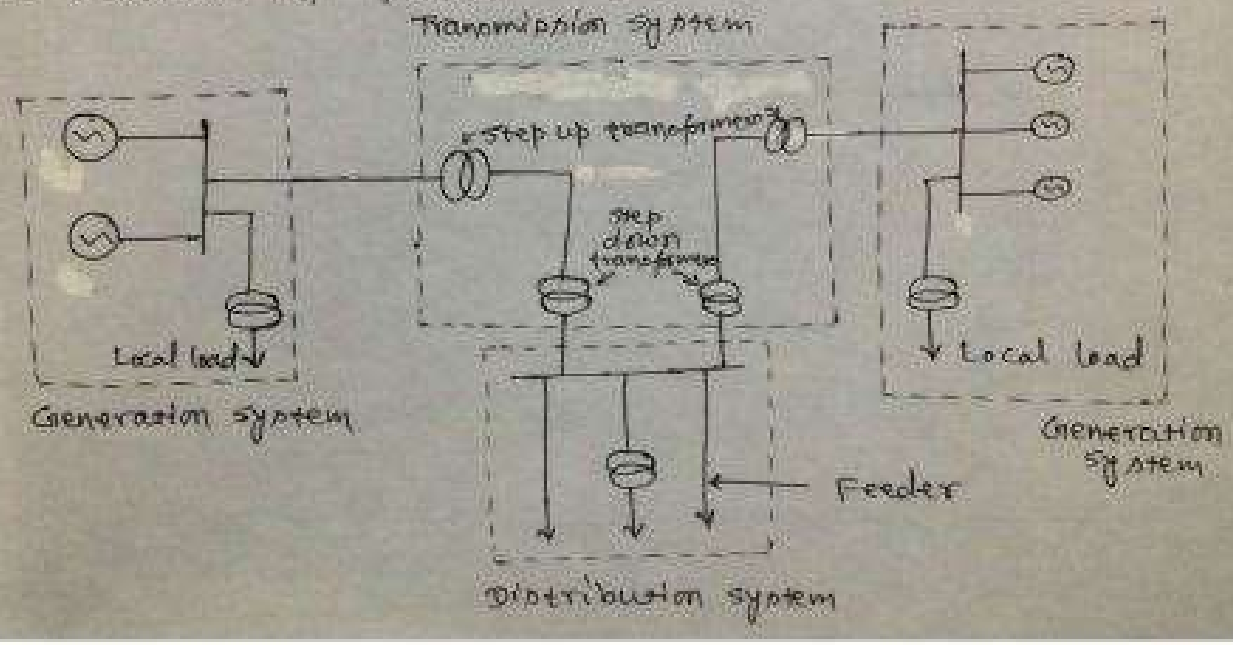
2. Transmission system:

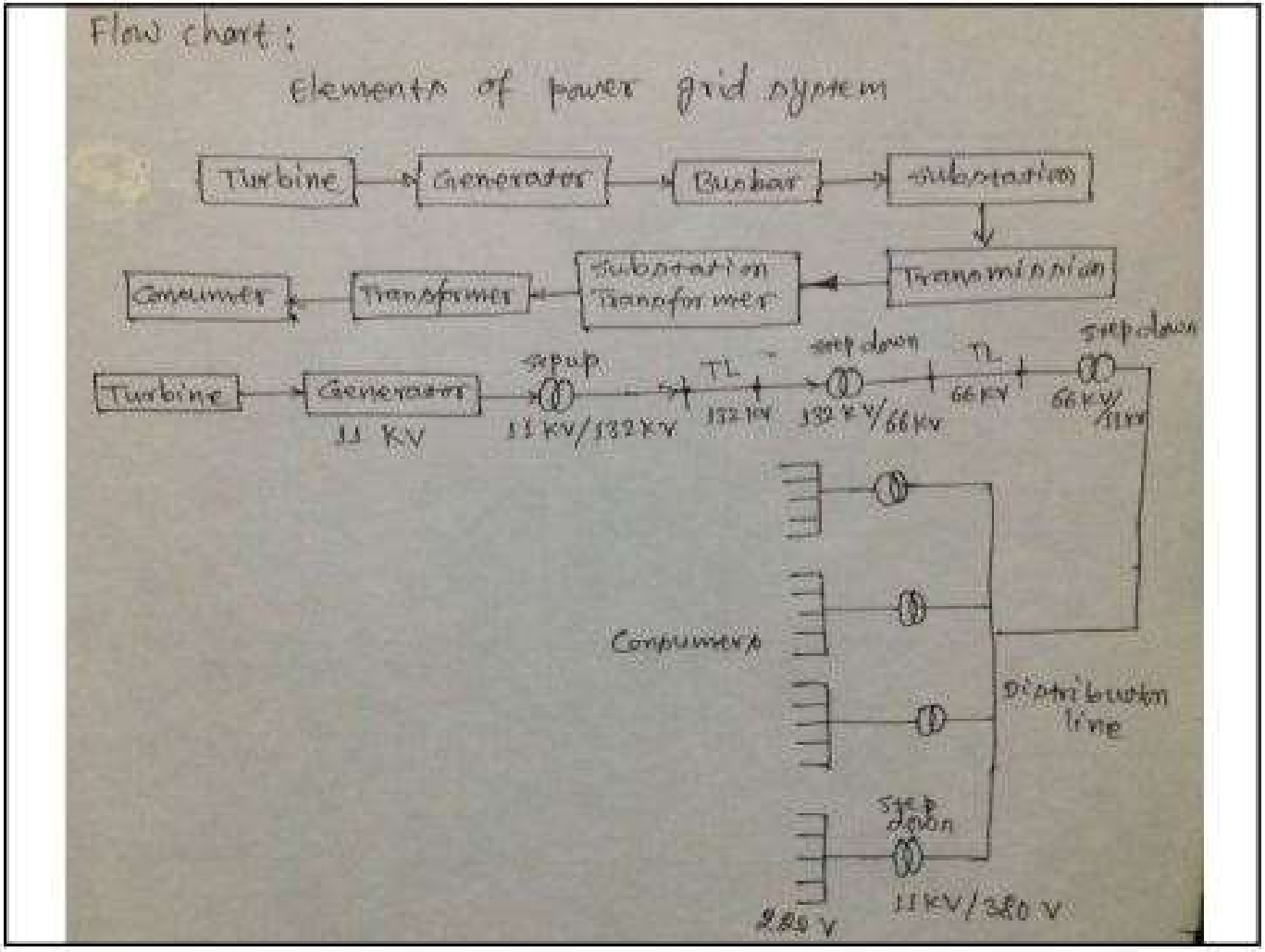
The function of transmission system is to transmit the power generated at generation station to the load centres or distribution sub-station. It consists of step up transformer at generation end and step down

transformer at distribution substation, which is end of transmission system.

3. Distribution system:

The function of distribution system is to supply the power to the consumers from distribution substation. It consists of feeders and distribution transformers.




Flow chart :
Elements of power grid system
Turbine
Generator
Busbar
Substation
Transmission
Substation transformer
Transformer
Consumer
Turbine
Generator
11 KV
step up
11KV/132KV
TL
132 KV
step down
132 KV/66KV
TL
66 KV
step down
66 KV/11KV
Consumers
Distribution line
Step down
11KV/380 V
380 V

Example 24.1. *The load on a hydel plant varies from a minimum of 10,000 kW to a maximum of 35,000 kW. Two turbo-generators of capacities 22,000 kW each have been installed. Calculate :*

(a) total installed capacity of the plant ;

(b) plant factor ;

(c) maximum demand ;

(d) load factor ;

(e) utilisation factor.

Solution. (*a*) Since two generators, each of capacity 22000 kW are installed, we have

the *total installed capacity* $= 2 \times 22000\ \text{kW} = 44000\ \text{kW}$. **Ans.**

(*b*) *Plant factor* (*i.e.* capacity factor)

$$= \frac{\text{Energy actually produced in time } t}{\text{Max. energy that can be produced in time } t}$$

$$= \frac{\frac{(10000 + 35000)}{2} \times t}{44000 \times t} = \frac{22500}{44000} = 0.511, \textit{i.e.}\ 51.1\%.\ \textbf{Ans.}$$

(*c*) *Maximum demand* = 35000 kW (as given). **Ans.**

(d) *Load factor* $= \dfrac{\text{Average load over a certain period}}{\text{Peak load during that period}}$

$$= \frac{\dfrac{10000 + 35000}{2}\ \text{kW}}{35000\ \text{kW}} = \frac{22500}{35000} = 0.643\ \textit{i.e.}\ 64.3\%.\ \textbf{Ans.}$$

(e) *Utilisation factor* $= \dfrac{\text{Max. power utilised}}{\text{Max. power available}}$

$$= \frac{35000\ \text{kW}}{44000\ \text{kW}} = 0.795, \textit{i.e.}\ 79.5\%.\ \textbf{Ans.}$$

Example 24.2. *A common load is shared by two hydel stations : one being a base load station with 20 MW installed capacity, and the other being a stand-by station with 25 MW capacity. The yearly output of the stand-by station is* 10×10^6 *kWh and that of the base load plant as* 110×10^6 *kWh. The peak load taken by stand-by station is 12 MW and this station works for 2500 hours during the year. The base load station takes a peak of 18 MW. Find out :*

(a) Annual load factors for both stations.

(b) Plant use factors for both stations.

(c) Capacity factors for both stations.

Q. The load on a hydropower plant varies from minimum of 10 MW to 35 MW. Two turbo generator of capacities 22 MW installed. Calculate load factor, plant factor and utilization factor.

Sol:

$$\text{Average load} = \frac{10+35}{2} = 22.5 \text{ MW}$$

$$\text{total plant capacity} = 2 \times 22 \text{ MW} = 44 \text{ MW}$$

$$\text{Load factor} = \frac{\text{Avg. load}}{\text{peak load}} = \frac{22.5}{35} = 0.64$$

$$\text{capacity or plant factor} = \frac{\text{Avg. output of the plant}}{\text{plant capacity}}$$

$$= \frac{22.5 \text{ MW}}{44 \text{ MW}}$$

$$= 0.51$$

$$\text{Utilization factor} = \frac{\text{peak load}}{\text{installed capacity}}$$

$$= \frac{35 \text{ MW}}{44 \text{ MW}}$$

$$= 0.79$$

Solution. We will work out all the required three factors for the base load plant first, and then for the other stand-by plant.

For Base Load Plant. For this base load station, data is given as :

Installed capacity $= 20\ \text{MW} = 20 \times 10^3\ \text{kW}$

Yearly output $= 110 \times 10^6\ \text{kWh}$

Peak load taken $= 18\ \text{MW} = 18 \times 10^3\ \text{kW}$.

(*a*) Now, *Annual load factor*

$$= \frac{\text{Total energy (kWh) generated per year}}{\text{Max. power demand in kW} \times 365 \times 24}$$

$$= \frac{110 \times 10^6}{(18 \times 10^3) \times 365 \times 24} = \mathbf{0.698}, \textit{i.e.}\ \mathbf{69.8\%}. \quad \textbf{Ans.}$$

(*b*) *Plant use factor* $= \dfrac{\text{Max. power utilised}}{\text{Max. power available}}$

$$= \frac{18000\ \text{kW}}{20 \times 10^3\ \text{kW}} = \mathbf{0.9}, \textit{i.e.}\ \mathbf{90\%}. \quad \textbf{Ans.}$$

(*c*) *Capacity factor* $= \dfrac{\text{Av. energy utilised in a period (year)}}{\text{Max. energy that can be produced in that period}}$

$$= \frac{110 \times 10^6}{(20 \times 10^3) \times (24 \times 365)} = \mathbf{0.628}, \textit{i.e.}\ \mathbf{62.8\%} \quad \textbf{Ans.}$$

For stand by plant. The data given for this plant is :

Installed capacity = 25 MW = 25×10^3 kW

Yearly output in 2500 hrs = 10×10^6 kWh

Peak load = 12 MW = 12×10^3 kW.

No. of working hours during the year = 2500 hr.

(a) Annual load factor

$$= \frac{\text{Total kWh generated per year}}{\text{Max. power demand in kW} \times (24 \times 365)}$$

$$= \frac{10 \times 10^6 \text{ kWh}}{(12 \times 10^3 \text{ kW}) \times (24 \times 365 \text{ h})} = \mathbf{0.095, \textit{i.e.}\ 9.5\%.} \quad \textbf{Ans.}$$

(b) Plant use factor $= \dfrac{\text{Max. power utilised}}{\text{Max. available power}}$

$$= \frac{12 \times 10^3 \text{ kW}}{25 \times 10^3 \text{ kW}} = \mathbf{0.48, \textit{i.e.}, 48\%.} \quad \textbf{Ans.}$$

(c) Capacity factor $= \dfrac{\text{Av. output}}{\text{Station capacity}}$

$$= \frac{10 \times 10^6 \text{ kWh}}{(25 \times 10^3 \text{ kW}) \times 2500 \text{ h}} = \mathbf{0.16, \textit{i.e.}\ 16\%.} \quad \textbf{Ans.}$$

Example 24.4. *A run-off river plant with an installed capacity of 15,000 kW operates at 28% load factor when it serves as a peak load station :*

(a) What should be the minimum discharge in the stream, so that it may serve as a base load station ? The plant efficiency may be assumed to be 80% when working under a head of 20 m.

(b) Also calculate the maximum load factor of the plant when the discharge in the stream is 35 cumecs.

Solution. Installed capacity = 15,000 kW

Load factor = 28%

$$\text{Load factor} = \frac{\text{Av. Load}}{\text{Peak Load}}$$

The installed capacity plant serving as peak load plant means that the Installed capacity = Peak load.

$$\therefore \quad \text{Peak load} = \text{Installed capacity} = 15000 \text{ kW}$$

$$\therefore \quad 0.28 = \frac{\text{Av. load}}{15000}$$

$$\therefore \quad \text{Av. load} = 15000 \times 0.28 = \mathbf{4200 \text{ kW}}.$$

(*a*) Now, when this plant has to serve as base load plant, it should develop average load, *i.e.* 4200 kW.

Hence, Q reqd. to develop 4200 kW is given by :

$$P = 9.81 \eta \cdot Q \cdot H$$

or $$4200 = 9.81 \times 0.8 \times Q \times 20$$

$$\therefore \quad Q = \frac{4200}{9.81 \times 0.8 \times 20} = \mathbf{26.78 \text{ cumecs.}} \quad \textbf{Ans.}$$

(*b*) When discharge in the stream is 35 cumecs, then power developed

$$= 9.81 \eta \cdot QH$$

$$= 9.81 \times 0.8 \times 35 \times 20 \text{ kW} = \mathbf{5488 \text{ kW}}.$$

$$\text{Load factor} = \frac{\text{Av. power}}{\text{Peak power}} = \frac{5488 \text{ kW}}{15000 \text{ kW}} = 0.366, \textit{ i.e. } 36.6\%.$$

Hence, maximum load factor at 35 cumecs flow in the stream = **36.6 %.** Ans.

Example 22.10. *It is observed that a run-of-river plant operates as peak load plant with a weekly load factor of 25%, all this capacity being firm capacity. Determine the minimum flow in river so that power plant may act as a base load plant. The following data is supplied : Rated installed capacity of generating plant = 10 MW; operating head = 16 m; Plant efficiency = 86%.*

If the stream flow is 15 m^3/s, find the daily load factor of the plant.

Solution. Weekly load factor = 25%

Rated installed capacity of generating plant = 10 MW (= 10000 kW)

Operating head H = 16 m

Plant efficiency, η_0 = 86%

Minimum flow in river in m^3/sec, Q :

$\therefore$ Load factor $= \dfrac{\text{Average load}}{\text{Maximum demand}}$

$\therefore$ Average load = Load factor × maximum demand

$= 0.25 \times 10000 = 2500$ kW

E = Total energy generated in one *week*

$= 2500 \times 24 \times 7 = 42 \times 10^4$ kWh

Now, Power developed, $P = \eta_0 wQH$ kW

$= 0.86 \times 9.81 \times Q \times 16$ kW $= 134.98\,Q$ kW

$\therefore$ E_1 = Total energy generated in one *week*

$= 134.98\,Q \times 24 \times 7 = 22676.6\,Q$ kWh

Now, $E = E_1$

$$42 \times 10^4 = 22676.6Q$$

$$\therefore \quad Q = \frac{42 \times 10^4}{22676.6} = 18.52 \text{ m}^3/\text{s}$$

Hence, minimum flow rate = **18.52 m³/s. (Ans.)**

Power developed whe stream flow is 15 m³/s,

$$P_1 = 134.98 \times 15 = 2024.7 \text{ kW}$$

Energy generated per day,

$$E_2 = P_1 \times \text{time} = 2024.7 \times 24 = 48592.8 \text{ kWh}$$

$$\therefore \quad \textit{Daily load factor} = \frac{\text{Average load}}{\text{Maximum load}}$$

$$= \frac{48592.8}{10000 \times 24} = \textbf{0.2025 or 20.25\% (Ans.)}$$

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